NEW SOUTH WALES.

DEPARTMENT OF MINES AND AGRICULTURE.

GEOLOGICAL SURVEY.

E. F. PITTMAN, A.R.S.M., Government Geologist.

MINERAL RESOURCES.
No. 3.

NOTES ON GOLD DREDGING

WITH REFERENCE TO THE

INTRODUCTION OF THE INDUSTRY INTO NEW SOUTH WALES.

BY

J. B. JAQUET, A.R.S.M., F.G.S.,
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Geological Survey, New South Wales,
Department of Mines and Agriculture,
Sydney, 22nd March, 1898.

Sir,

I have the honor to submit for publication Report No. 3 of the Mineral Resources Series, entitled "Notes on Gold Dredging in New Zealand," by Mr. J. B. Jaquet, A.R.S.M., F.G.S., Geological Surveyor.

It has long been known that the gravel in the beds of many of our rivers in New South Wales contain considerable quantities of gold derived from the redistribution of older (Tertiary) leads, and also from the denudation of auriferous reefs which occur in the country bordering the river channels. The difficulties of mining in the presence of large bodies of water has hitherto prevented the economical extraction of the gold from the river beds of this Colony, but the success which has attended river-dredging in New Zealand has now raised the question whether similar results cannot be obtained here.

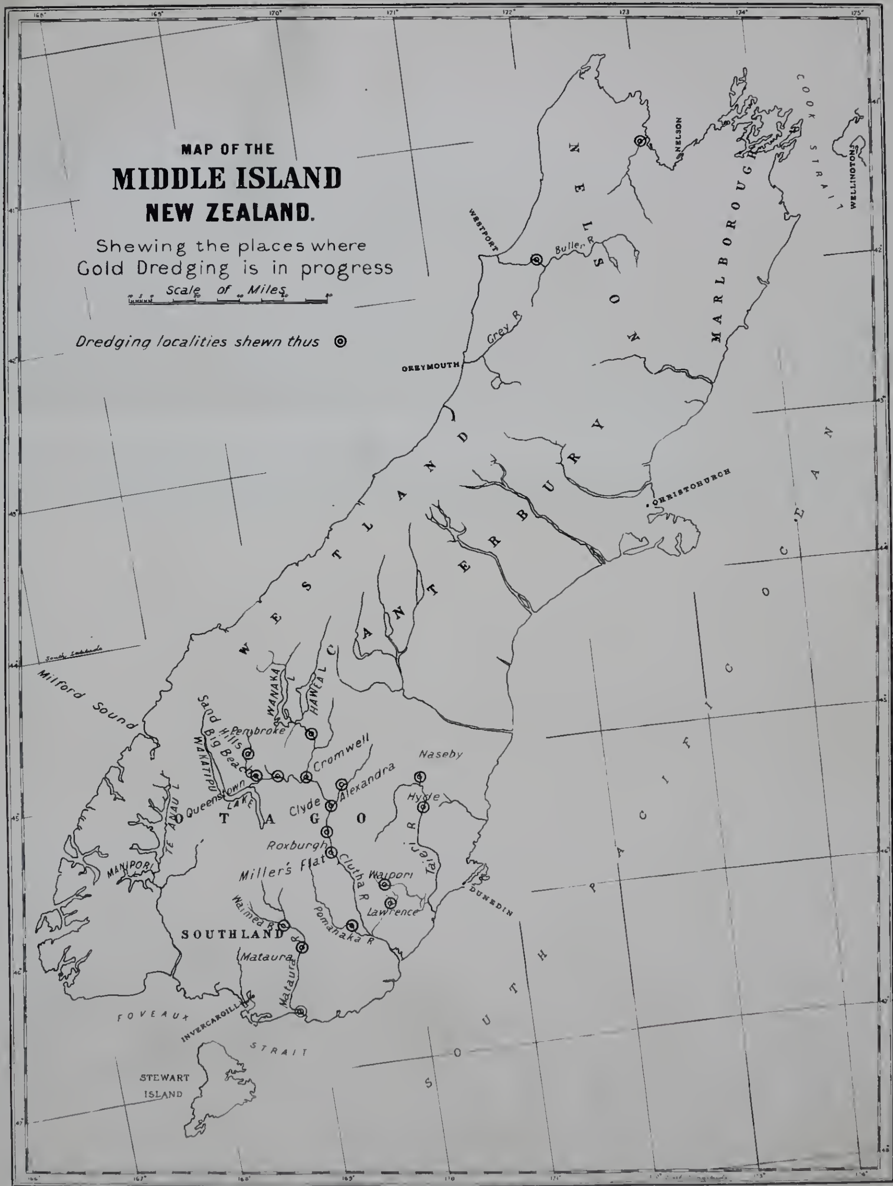
Advantage was taken of Mr. Jaquet's recent visit to New Zealand to obtain from him a report upon the results obtained, as well as the machinery in use there, and it is hoped that this report will be of use in assisting the introduction of the river-dredging industry into New South Wales. It is, therefore, recommended that it be published in pamphlet form for distribution.

I have the honor to be, Sir,

Your obedient Servant,

EDWARD F. PITTMAN,
Government Geologist.

The Under Secretary for
Mines and Agriculture.



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Miners accustomed to exploit the gold-bearing gravels upon river-banks, and tantalised so often by being obliged to cease following some rich "run" of ground on account of it having dipped underneath the stream, have always desired a method which would enable them to baffle the water and prosecute their industry upon the river-bed. They may frequently be seen to look with longing towards the rich treasure which they believe to lie concealed there.

A consideration of the general geology of river-basins would seem to encourage them in this view, and tends to show that the submerged gravels should certainly be as rich, if not richer, than any found elsewhere in the valley. In many valleys we have evidence of the number of times the river has changed its course in the deposits of gravel and other detritus which are situated at various distances from the flowing water. The extent of these deposits, the altitude at which they occur, and calculations as to the rate of erosion, enable us to relatively measure, or at any rate form some rough idea of, the age of the river; and upon these data geologists have come to the conclusion that many streams have been flowing over constantly changing courses for immense intervals of time. The process of building up a gravel bed is no sooner completed than that of decay commences. The disintegration may take place rapidly, as when the erratic river returns once more to one of its old courses, or it may take place so slowly as to be scarcely noticeable within a man's lifetime. However, it is always going on, and after a certain interval has elapsed—it may be many thousand years—the constituents of every bed will be once more travelling down the river to a new resting-place, and finally a new cycle of changes will commence.

Now, I think it will be apparent that I have been describing a natural process of sluicing. The miner will recognise that the crumbling beds of stranded detritus represent the ground in the face of his claim, and that the river may be looked upon as a great sluice-box. He will understand why, as a general rule in the case of auriferous drifts, the younger beds in the valley are richer than the older ones, and why we should look for the richest ground in the river itself where the youngest deposits of all are to be found.

Before the practice of dredging was introduced, it was only possible to win the gold from those portions of the river-bed from which the water could be diverted. Sometimes the stream was confined within smaller limits by means of a wing-dam ; or a spot would be selected where the river flowing back on itself formed a "horse-shoe bend," so that the whole of the water could be diverted from a portion of the bed by means of a tunnel driven through the narrow neck of land.

The industry originated and has been brought to its present state of perfection upon the Clutha River, in the province of Otago, New Zealand. It has made considerable progress within the last few years, and has done much towards creating an era of increased prosperity in the province. Many mining townships which were ailing a short time ago, on account of gold-getting from ordinary sources having decreased, have had new life infused into them, and have once more become important centres of activity. A large amount of employment at good wages has been found, both for dredge-hands and mechanics, the latter being engaged in manufacturing and repairing dredges in the Dunedin workshops. About fifty dredges are now at work upon the Clutha and its tributaries.

I intended to have given particulars of the gold yields obtained by the various companies who publish returns. I find, however, that many of the most successful machines are privately owned, and no returns are available, so to do this would be to convey a wrong impression altogether as to the magnitude of the industry. A few remarkable yields recently obtained, and selected at random from those which came under my notice, will show how quickly the capital sunk in the industry has been in some instances recovered. The Electric No. 2 dredge, working near Cromwell, which cost £5,000 to build and launch, obtained more than this amount of gold within seven weeks after she started to work. A small "current-wheel" machine, working about a mile below Alexandra, obtained gold to the value of £3,570 during two months of last winter. The "Moa," belonging to the Clyde Dredging Company, Limited, a company which has only a capital of £4,000, for nine months' work, ending in September last year, obtained gold to the value of £10,156.

The quantity of gold which escapes the well-equipped modern dredge is small, and it is not possible under ordinary circumstances to profitably rework ground, so we may expect the rich bed of the Clutha to be worked out in a few years' time. However, the dredging industry will not cease with the exhaustion of this treasure. To such a state of perfection has it been brought that ground containing only a grain or a grain and a half of gold per cubic yard can now be worked at a profit ; and, moreover, under certain conditions a dredge is able to cut a channel for itself through the river-bank and wander at the will of the engineer in charge over the bordering flats ; or it may be launched to work low-lying auriferous flats, far removed from any river at all. Under the new conditions the yields of gold are not likely to be so sensational, but they will probably be more regular than they have been in the past.

A sketch map of the Middle Island of New Zealand will be found facing the first page of this paper, upon which the localities where dredging operations have been carried out are indicated.

The Clutha River.

The Clutha, also called Molyneux, carries down to the sea an enormous volume of water. "In 1864 the Provisional Government had the volume of the river carefully measured at a time when its waters were low, and the result was found to be something extraordinary, being not less than 1,690,400 cubic feet per minute. The following comparison with other large rivers was published at the time:—

	Cubic ft. per min.
Molyneux	1,690,400
Tay	274,000
Boyne	180,000
Thames	102,000
Clyde	48,000
Rhine	3,960,000
Rhone	649,000
Tiber	618,000
Saone	460,000
Arno	266,000
Nile	1,386,000
Irrawaddy	4,500,000

Thus the Clutha River, when at its lowest, was found to be larger than the Nile, six times the size of the Tay, nine times that of the Boyne, and sixteen times that of the Thames."* More recently, the late inspecting engineer, Mr. H. A. Gordon, has estimated the discharge of the Clutha as follows:—

	Cubic ft. per min.
Minimum	837,000
Maximum	5,040,000
Average	1,674,000

Being chiefly dependent upon the snows of the Southern Alps for its supply of water, the flow is consequently greatest during the summer months, and reaches a minimum in winter.

The Clutha itself heads from Lakes Wanaka and Hawea, and its chief tributary, the Kawaru, from Lake Wakatipu. These three lakes play an important part in the economy of the river. They cover in the aggregate an area of 237 square miles, and, by acting as reservoirs, regulate the flow and prevent floods occurring. The fall of the river from its source in Lake Wanaka to the sea averages about 10 feet per mile, and the current is for the most part very rapid.

The country upon the banks varies greatly in character. Here the water tumbles impetuously through a rocky gorge, where the mountains rise abruptly on either side, and elsewhere, it will flow, still travelling hurriedly, through extensive low-lying flats. The dominant rocks are contorted and much altered slates and schists, of Palæozoic age, which are overlain in places by horizontally bedded clays and sandstones. Interstratified with the latter rocks are beds of lignite. Central Otago is absolutely devoid of timber, and, by providing a cheap fuel for steaming purposes, these lignite beds have greatly assisted the dredging industry.

There are many auriferous rivers in Australasia, yet for a number of years has the practice of dredging been practically confined to the Clutha and its tributaries, and the question will arise: In what way does this New Zealand river differ from the others, and how is it better adapted for this method of gold-winning? As regards its swift current and large volume of water, the Clutha is certainly far ahead of other rivers in these colonies; it is also probably unique as regards the extent, richness, and general arrangement of its submerged gravels. There is, however, much to show that the first-mentioned characteristics have, on the whole, tended to retard rather than

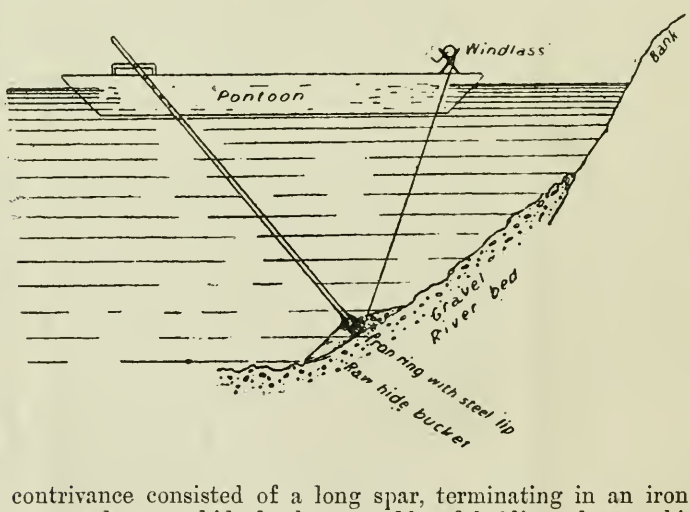
* Handbook of New Zealand Mines, Wellington, 1887, p. 38.

assist the industry. The best results have been obtained during the winter months, when the volume of water is at a minimum; indeed, many dredges are obliged to suspend operations altogether in summer. It is true, as I shall point out elsewhere, that, at one period in the history of the industry, the swiftly flowing water may have rendered good service by supplying power. Again, it may be of assistance in taking away the tailings. Yet it should be remembered on the other hand that a flow strong enough to carry off the tailings astern will also bring down silt from above, and deposit it in the "paddock" where the buckets are at work. When I was inspecting the Shotover River, a warm night, by accelerating the rate of melting of the snows upon the mountains, produced a slight fresh, and one of the dredges had to cease work for twelve hours, owing to the silt being deposited at a greater rate than it could be elevated. The best use is made of the current when the dredge can be moored, so that the buckets excavate into the bank or under still water, and only the elevator or tailings-shoot projects over into the running stream. The modern dredge certainly works to greater advantage in still shallow water, always provided that there is sufficient water to float the machine and wash the elevated gravel.

On the whole, I think the leading position occupied by the Clutha must be ascribed to its great wealth in alluvial deposits, and to the fact of the industry having been cradled and perfected upon its waters.

The Evolution of the Modern Dredge.

Spoon Dredges.—These primitive machines have been employed upon the Clutha ever since 1864. Their remains are to be seen in many places upon the river banks. They have also been occasionally used upon the Macquarie, and other rivers in our Colony. The sketch below is the outcome of descriptions given to me by miners and others.



The contrivance consisted of a long spar, terminating in an iron hoop, which supported a cow-hide bucket, capable of holding about a third of a ton of gravel. The spar swung upon a pivot placed near the stern of the pontoon, and was raised and lowered by means of a windlass erected in the bow. The dirt was emptied out of the bucket on to the deck, and was afterwards washed in an ordinary miners' cradle.

A spoon dredge, even under the most favourable conditions, could only treat 2 or 3 tons of gravel per hour, as against the 100 tons which the modern steam dredge is capable of dealing with in the same period. Nevertheless, in the early days of gold-mining upon the Clutha, when the virgin ground in the river was not buried beneath vast deposits of tailings, as is the case to-day, good results were obtained, and not a few small fortunes built up as the result of the operation of these machines.

Current-wheel Dredges.—The next dredges placed upon the river lifted the gravel with a chain of buckets, and being provided with undershot wheels, derived their power from the river current (*see Plate VII*). The buckets discharged into sluice-boxes, which were supplied with water by a centrifugal pump. One or two of these machines are still upon the river, and from time to time do good work. The advantages which they possess as compared with steam dredges are as follows :—(*a*) Small first cost; (*b*) no fuel is consumed ; (*c*) fewer hands are required. They labour, however, under one great disadvantage—being dependent upon the current for power, they are always obliged to keep well out in the stream, where during a considerable portion of the year the water may be too deep, or the deposit of silt too great, to permit of work being continued.

Steam Dredges were first launched upon the Clutha in 1881. They only differed essentially from the machines then upon the river in being provided with boiler and engines. They are able, when the river is high, to work along the bank or, by running up into the eddies and backwaters, in places where a minimum amount of silt is being deposited. Hence, with the introduction of steam, stoppages have been of shorter duration, and work has proceeded more regularly.

The introduction of a tailing-elevator.—When a dredge is working in still water there is always a tendency for the tailings to find their way back again into the excavation being made by the buckets. In designing the first machines endeavour was made to overcome this evil by raising the top tumbler, and causing the dirt to be discharged at as high an elevation as possible, so that sufficient fall might be obtained to permit of a long shoot being carried over the stern, by means of which the tailings could be discharged at some distance behind the pontoon. The limit to which it is possible to elevate in this manner is soon reached; and, moreover, the adaptation of this method tended to impair the general efficiency of the whole machine.

The difficulty was eventually overcome by lifting and stacking the tailings from the stern of the dredge by means of a bucket-elevator. The improvement was first applied by Messrs. Cutten Brothers, of Dunedin, to the "Enterprise" dredge (Plate VI), which was employed in working a beach upon the Clutha, near Alexandra. It may be said to have effected a revolution in the industry. The old machines were obliged to confine their operations to the rivers; the new ones, armed with an elevator, have been successfully employed in exploiting low-lying auriferous flats.

Sand pumps.—Attempts have been made to exploit the gravels of the Clutha River by means of suction pumps, but in every instance have failed. Similar results would seem to have been obtained in Montana, United States of America, where these machines were tested prior to the introduction of bucket-dredges.

The machines consisted essentially of a pontoon supplied with a powerful pump, which delivered its contents into sluice-boxes. As an instance of the costliness of the process, I may mention that a suction dredge working upon the Waiparapa Beach, near the mouth of the Mataaura River, was found to require 60 I.H.P. to lift on an average 15 tons of gravel per hour whereas a bucket-dredge of 30 I.H.P. would lift many times this amount in the same time.

General Description of a large Dredge.

The tendency at the present time seems to be to build larger machines. The initial cost under these circumstances is greater, and more fuel is consumed; but on the other hand, the cost for labour is the same as on a smaller dredge, and an increase quantity of gravel is treated.

The Electric Company's No. 3 Dredge.—This machine was being built at the period of my visit. When completed, it will be the largest dredge employed in gold-winning in New Zealand. It is expected that it will be launched in about five months' time to work ground upon the Kawarua River, about 3 miles above Cromwell. The pontoons are 120 ft. by 10 ft. by 7 ft., and are built in one piece. The well hole is 88 ft. long by 5 ft. wide. The deck beams project 2 ft. 6 in. on either side, so that the deck will be 30 ft. wide. The planking is kauri; the frames Tasmanian hardwood; and the stringers ironbark. The ladder will be 75 ft. long. The bucket belt will be made up of forty buckets and four sets of powerful grab hooks. Each bucket will weigh 10 cwt., and, having a full capacity of 6 cubic ft., will hold 5 cubic ft. when inclined at an average dredging angle. The total weight of the ladder and buckets will be 40 tons. A steam winch will be provided with six barrels. The revolving screen will be 22 ft. long and 4 ft. 5 in. in diameter. The tables for catching the gold will be 18 ft. wide and 17 ft. long. They will have a fall of $1\frac{1}{2}$ inches in the foot. The screen will be supplied with water by a 10-inch centrifugal pump. The elevator will be 35 ft. between centres. Power will be obtained from a 16 H.P. horizontal compound Marshall engine, which will derive its steam from a half Lancashire and half tubular boiler, with a fire-grate area of 20 sq. ft. The total weight of the pontoons, with all the machinery, will be 200 tons. The expense of building and launching such a dredge will be about £6,000. Theoretically it will be able to elevate and wash 133 cub. yds. of gravel per hour.

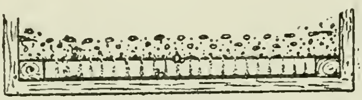
The majority of the dredges upon the Clutha are very much smaller than the one described above. The buckets upon the Molyneux Hydraulic Company dredge have only a full capacity of $4\frac{1}{2}$ cubic ft., and those upon the "Moa" only hold 3 cubic ft., while other dimensions are about in proportion. The length of ladder depends upon the depth of ground which is to be worked. It is not advisable to have the ladder too long, since under these circumstances the buckets are always inclined at a low angle, and their working capacity is, in consequence, lowered.

The frames and plating of some of the pontoons are made of steel, but experience seems to have shown that timber is better adapted for this purpose.

One plant—the Sandhills dredge—engaged in exploiting the upper Shotover, deserves some mention, in so far as it is the only one in New Zealand which is driven by electrical power. The pontoons are constructed of steel. They are 80 ft. long, and the deck has a width of 20 ft. The buckets have a full capacity of $3\frac{1}{2}$ cub. ft., and discharge at the rate of twelve per minute. This I found to be the rate of discharge adopted upon all dredges. The dynamos derive their power from a Pelton wheel driven by a stream of water, which has been imprisoned upon the mountain side at a height of 524 ft. above the power-house. There are two motors upon the dredge, one of which drives the chain of buckets and the winches, while the other drives the centrifugal pump. At the time of my inspection the dredge was working at a distance of 3 miles from the dynamos generating the current. The cost of the dredge was £2,600, and of the whole installation £7,000. A full account of the plant will be found in the paper which has been contributed to the Institute of Civil Engineers, London, by Mr. Robert Hay, M. Inst. C.E.*

Gold-saving Appliances.

Upon the older dredges, and upon a few of the modern ones, the buckets discharge their contents by way of a shoot into ordinary sluice-boxes. The average length of boxes is 30 feet, and the fall about 1 in 12. The gold is caught either upon cocoa-nut matting or plush. Sometimes the boxes are provided with ordinary ripples, but more often they are fitted with punched iron plates, as shown in the section through a sluice-box given below. The



a. Iron plate, ¼-in. thick, with holes punched 1 in. apart.
b. Cocoa-nut matting.

large stones travel down upon the iron plates; the finer material and gold is washed by the water through the apertures, the latter being caught upon the matting. When the gold is very coarse tramway rails laid across the boxes have answered admirably as ripples. Mr. R. White has invented an arrangement of curved rail ripples, and applied the same to the Sandhills dredge under his charge. The curved rails ensure a more even lateral distribution of the material being sluiced.

With the introduction of the revolving screen a great advance was made in the process of treatment. The buckets discharge their contents into a shoot which leads into the upper end of the screen. Here a spray of water washes the fine material and gold through the perforations directly on to the tables arranged below, and the screenings are delivered by a shoot from the end of the screen into the buckets of the elevator, or, in the case of the older machines, directly into the river. The screens vary in length from 10 to 22 feet, and in diameter from 3 to 4 ft. 6 in. They make about ten revolutions per minute. The two screws upon the Molyneux Hydraulic Company's dredge have angle-iron worms inside, so that all the material passing into them, travels eight times the circumference of screen while under the influence of the water. In order to ensure a more even distribution of the fine sludge upon the tables, the perforations near the head of the screen are either of smaller size or are fewer in number than elsewhere. Water is supplied by means of a spray-pipe which enters the screen from behind. From 1,200 to 2,000 gallons of water per minute are required to ensure efficient washing.

* Pro. Inst. of Civ. Eng., vol. CXXI, Par. III.

The tables for catching the gold are upon most dredges arranged in three shelves, so that the centre of each table is equidistant below the screen. They have in the aggregate a width equal to the length of the screen, a length of from 10 to 14 ft., and a fall of 1½ to 1¾ in. to the foot. They are covered either with cocoanut-matting or plush, which is overlain with ¼-in. mesh rectangular wire-netting. The latter is found to answer admirably as ripples. The percentage of gold which is lost in treatment upon the best-equipped dredges is probably very small.

That the tables equipped as above are capable of saving extremely fine gold has been shown by measurements which have been made of the particles. "A sample of fine gold from the Electric Company's dredges, about 2 grains in weight, which had been sifted through a sieve of about 3,600 holes to the inch was again sifted through one of 4,900 holes, and the gold which passed through sorted under a powerful lens. One hundred of the smallest of these pieces were thus selected, and examined under a microscope. Measured with a micrometer, their dimensions in fractions of an inch varied between 0·009 x 0·006 and 0·003 x 0·002, the mean of twenty measurements being 0·0065 x 0·0042. The hundred particles were then carefully weighed, and found to have a mass of 0·097 of grain. The mean weight of the pieces was therefore 0·00097, or a little under one-thousandth of a grain."* I have measured a number of particles of gold comprised in a parcel from the Electric Company's dredges, and obtained results almost identical with those given above.

The Dredge at Work.

To keep a large dredge running continuously a crew of six men are employed. The ordinary wage being £3 per week. The manager or dredge-master is usually a skilled engineer in receipt of from £4 to £6 per week. He does not as a rule work upon shift, but lives somewhere close handy to the machine, so that he can be quickly upon the spot in the event of any breakdown occurring. It often is arranged so that one manager has several dredges under his control.

A good system of partly paying the men by results has been introduced by the owners of the Turakina dredge, Messrs. Park. The men receive 8s. 4d. per shift, and a bonus of 10s. per week in the event of the weekly yield of gold exceeding 20 oz., and 15s. if it exceeds 30 oz. This method seems to me to be an admirable one. A dredge hand requires to use his head more than his hands, and there is scope in the work for the display of a considerable amount of judgment. The chief desideratum is to keep the machine running as continuously as possible and the buckets fully charged.

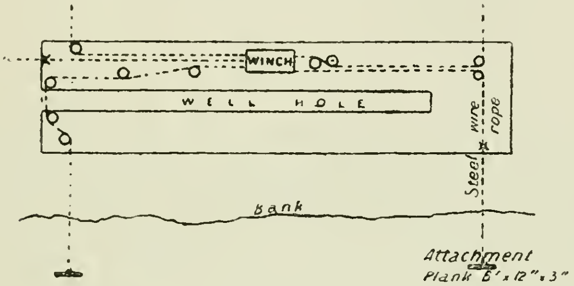
Two men are employed per shift. One attends to the winches, and the other does the stoking and looks after the engine. Before the introduction of the revolving screen the services of a third man were often required for the purpose of looking after the sluice-boxes. The winch-man is in charge of the shift; he keeps the dredge up to her work, and always keeps the up-coming buckets in view. Should a large boulder be lifted which is likely to damage the screen, he either breaks it when passing with a sledge hammer, or when it is not possible to do this stops the engine and levers it off.

* New Zealand Mining Journal, 1 Sept., 1897, p. 296.

Boulders up to a ton in weight are sometimes raised upon the grab-hooks. When after several attempts it has been found impossible to raise one of these obstacles, endeavour is made by excavating a hole with the buckets alongside to cause it to roll from its position.

The dredge is kept in position by means of five steel-wire mooring lines, two starboard lines, two port lines, and one head line. The shore ends of the lines are passed around stout planks and buried in the soil. Each dredge is provided with an anchor, to be used in case of emergency.

Sketch illustrating Method of Mooring Dredge.



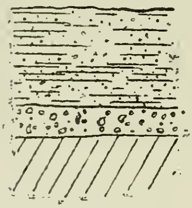
A dredge working into a flat cuts a passage for itself, breaking down the gravel in front and stacking it behind after it has been delivered of its associated gold. The greatest depth of ground (height of face) which it is possible to work is limited by the height of the elevator. In this connection it should be remembered that the elevated and loosely-packed gravel occupies a much greater bulk than when occurring *in situ*, consequently the depth of ground which it is possible for any dredge to work is always considerably below the height to which the same dredge is capable of elevating.

The Molyneux Hydraulic Company's dredge and other large machines can stack tailings up to a height of about 40 feet.

Dredge can be shifted over rapids or low falls.—This has been successfully accomplished upon the Shotover River by the manager of the Sandhills dredge, Mr. R. White, a system of locks being employed. The dredge is 95 feet long, and draws 2 ft. 6 in. of water. It is only when the river is in flood that there is sufficient water to float her; under ordinary conditions she has to cut a channel for herself. The greatest fall that has been negotiated is 15 feet in a length of 2 chains. Some of the rougher projecting rocks are first of all removed by a few charges of dynamite. The dredge is then hauled up as closely as possible to the rushing water, and a rude stone weir is built immediately behind it. This weir by impounding the water enables a forward movement to be made when a fresh wall is built, and the process is repeated until the top of the fall is reached. Four stone walls were required in the case of the highest fall, and the cost of the whole operation was trifling.

Problems for the Future.

Many low-lying auriferous flats are seen when examined in section to be made up as shown below.



Under these circumstances a difficulty will be experienced in keeping the dredge afloat, for the fine material, by passing through the apertures of the screen, will escape the elevator and be deposited around and underneath the pontoon. When the dredge attacks the flat from a swift-flowing river like the Clutha it may be possible by a judicious disposal of the tailings to divert a portion of the water so that there is always sufficient current astern to carry off the silt. However, the obstacle would be fatal to operations carried out in shallow still water in the absence of special precautions. An easy solution of the problem could be found in pumping the whole of the sluice-water with the fine material in suspension over the tailings heap; but this would necessitate a most extravagant expenditure of power. At least 1,600 gallons of water per minute are consumed in the washing-plant of an ordinary dredge; so, in the event of the tailings being stacked at an elevation of 20 feet, over 10 h.p. will be absorbed in lifting the water alone, where 16 h.p. is sufficient for all purpose upon the largest dredge. Engineers have for some time past been endeavouring to devise a method of overcoming the difficulty, and speak hopefully of being finally able to do so.

In one instauce the pontoon was provided with a settling tank and small bucket elevator, which lifted the deposited silt and discharged it into the main elevator, so that it was carried up and stacked with the screenings. This arrangement does not seem to have answered very well. The elevator working in the sandy sludge was soon destroyed; and, moreover, no method of adjustment was provided, so the contrivance could not be used to work ground containing a constantly varying quantity of fine material.

Another obstacle which has caused dredge-owners to look askance at considerable stretches of river, which are otherwise well adapted for their purpose, is a hard, rough bottom.

A small quantity of very fine gold is scattered throughout the Clutha drifts; but the greater portion—at least 80 per cent.—is found in the crevices of the bedrock or in the layers of gravel immediately adjacent. Such being the case, it is evident that success depends in a great measure upon whether the upper layer of rock is soft enough to permit of its being scooped up by the buckets. Under other conditions not only is the gold not obtained from the crevices, but the motion of the buckets is impeded and likely to be suddenly checked by projecting rocks.

The clayey sandstones which occur upon the river at Cromwell and elsewhere form an ideal bottom to work upon; but a difficulty is often experienced in those localities where the gravels rest upon the older slates and schists. It is necessary, however, that one should be very cautious in expressing an opinion as to whether a river-bottom is adapted for dredging or otherwise. Indeed, when the drift deposits extend to a great depth this question can only be satisfactorily answered after prospecting operations have been carried out. In several places upon the Clutha the same schists, which appear hard and unyielding upon the bank, have been found to be soft and pliable beneath the river.

In working upon flats or in shallow, sluggish rivers—and the majority of our New South Wales rivers are of this character—it may be possible to dredge close down to the bottom, and finally clean the same with the aid of divers. For the purpose of raising the small quantity of gravel which the buckets were unable to reach, and for cleaning out the crevices, sand-pumps controlled by the divers might, perhaps, be used with advantage. The rapid current would render it dangerous to employ divers upon the Clutha.

In this connection it is important to note that the gold in many river drifts is not confined to the bottom, but is more or less evenly distributed through a considerable thickness of gravel, or a portion of it may have been deposited upon a false bottom at some distance above the bedrock. While prospecting the auriferous gravels upon the Shoalhaven River, in 1893, I obtained, in many instances, a higher yield of gold from a false bottom than from the bedrock below; and several beds of gravel were tested in which no concentration of the precious metal upon the bottom could be detected. It is obvious that, under such circumstances, dredging might be profitably carried on, notwithstanding the presence of a hard rough bottom.

Another impediment to the industry is to be found in the occurrence of decaying logs or tree stumps. The Clutha is practically free from these obstacles; but they have given considerable trouble to the dredges working the Buller River, upon the west coast of New Zealand.

In the event of the auriferous ground being clayey there will be a tendency for it to adhere to the buckets. This might, perhaps, be provided for by causing a spray of water to play into them when they are discharging their contents. A much more serious difficulty will arise, however, in the event of the clay being present in sufficient quantity to render puddling necessary as a preliminary operation to the ordinary treatment. The process, besides absorbing a large quantity of water, is long and tedious; and, even should it be possible to successfully carry it out upon a dredge, its introduction would of necessity considerably lower the output.

Working Expenses of Dredge.

The weekly cost of running a large dredge in New Zealand is as follows:—

	£	s.	d.
Fuel—16 tons of lignite at 12s.	9	12	0
Labour—5 men at £3 and 1 at £5	20	0	0
Repairs, office expenses, &c.	20	0	0
	49	12	0

A large dredge working favourable ground is capable of elevating and washing at least 90 cubic yards of gravel per hour. For instance, the buckets upon the Molyneux Hydraulic Company's dredge have a capacity of 4½ cubic feet, say $3\frac{1}{2}$ cubic feet when inclined at an average dredging angle, and twelve bucket-loads are delivered per minute, so there should be 93 cubic yards delivered per hour. Suppose such a dredge to work twenty-two hours out of every twenty-four, and six days per week, then it will treat 12,276 cubic yards per week. Now, as the gravel in the buckets will be loosely packed and occupy a larger space than when in situ, an allowance must be made, and I propose to reduce the above amount by one quarter, this will leave it at 9,207. Suppose the gravel to contain gold at the rate of a grain (in round numbers a value of 2d.) per cubic yard, then the value of the precious metal won per week would be £76. Deduct 10 per cent. for loss in treatment (the loss under ordinary circumstances is nothing like as great as this), and the amount becomes £69. Again deduct the working expenses of the dredge £50, and £19 will remain. Hence it is possible by means of a large dredge to work ground containing only a grain of gold per yard at a profit. It must always be remembered, however, that the quantity of material which a dredge is capable of raising within a certain time varies considerably with the nature of the ground.

As an instance of the profits obtained in dredging low-grade ground, I will quote the published returns of the Jutland Flat (Waipori) Gold-mining Company for two years :—

	1896.	1897.
Dredging wages time for period	6,171	5,846 hours.
Actual lifting during same period	5,678	5,518 ,,
Estimated quantity lifted	402,919	398,608 cub. yds.
Gold obtained	1,135	1,177 oz.
Average yield of ground	1·35	1·41 grs. per yd.
Paid in dividends	£1,125	£1,875

During 1896, £707 was expended in litigation. If this amount is added to the dividends paid, the actual profit for this year, after deducting all working expenses, will stand at £1,832.

Gold Dredging in Montana, U.S.A.

I am indebted to an article contributed to the *Engineering and Mining Journal* by Mr. E. B. Braden, for all the information contained under this heading.*

Two varieties of machine are being employed—floating dredges, which have been constructed after the fashion of those working upon the Clutha River, and "Traction" dredges, which travel upon wheels, and are designed to work upon dry land. "River (floating) dredges are successfully operating on Grasshopper Creek in Beaver Head County ; Traction or land mining machines are working satisfactorily at Washington Gulch, Deer Lodge County, and in Alder Gulch, near Virginia City."

The raising of auriferous gravel by means of suction pumps was tried first of all, and resulted, as was the case in New Zealand, in failure.

The first attempt to use a bucket dredge was made three years ago, but it was not until the dredge had been rebuilt twice that satisfactory results were obtained.

"The 'A. E. Graeter' was launched for the Bannock Dredging Company last June, and a plant for the Bon Accord Mines is almost completed. It is 102 feet in length, 32 feet wide, and draws 3 feet of water. With the

* Gold Dredging in Montana: Eugene B. Braden, *Engineering and Mining Journal*, Nov 20, 1897, p. 605

engines, boilers, and other machinery carried, the total weight is nearly 700,000 lb. Steam is generated by two tubular steel boilers, of the locomotive type, with grates arranged to use pine and fir wood for fuel. There are thirty-five buckets, with a capacity of 5 cubic feet each, and excavations can be carried to a depth of 38 feet."

The dredge only seems to essentially differ from the larger New Zealand machines in regard to the arrangements for shifting and moving. "It is equipped at the rear end with two spud timbers 42 in. × 18 in. × 50 ft. in size, and weighing 11,000 lb. each. These are each fitted with a pointed steel wearing shoe at the lower end, and with the necessary gearing for raising and lowering. These spuds are for moving the dredge forward or backward, being alternately raised by means of hoisting cylinders of 24 tons capacity and dropped after the dredge has been swung by the engineer in the pilot-house through the cables passed around the front corners of the boat to a lateral anchorage. The boat is thus walked ahead. While excavating, one of these spuds rests in the gravel at the bottom, and forms a pivot, around which the boat is swung as the gravel is taken up. By means of the suspensory cables carrying the bucket-ladder, this ladder is lowered about 6 inches with each swing of the dredge around the anchored spud. Thus with the drag of the bucket a segment of gravel 6 inches deep and 8 feet wide is excavated. This lowering of the ladder continues until bedrock is reached. The bedrock, if yielding, is torn loose and brought up until barren of values."

The percentage of gold extracted is stated at 98 per cent. The cost of working gravel when steam is employed has been found to be 9 cents ($4\frac{1}{2}$ pence) per cubic yard. This includes labour, supplies, running repairs, and superintendence. On the "F. L. Graves," where electricity is employed for power, this cost has been $4\frac{1}{2}$ cents ($2\frac{1}{4}$ pence) per cubic yard.

"The traction dredge or land-mining machine at Washington Gulch has been designed to work in ground that is unusually flat, and where but little water is obtainable. It is owned and operated by W. M. Johnston & Co., of Chicago, who also designed the plant. The builders were the Marion Steam Shovel Company, and the Gates Ironworks. It works dry gravel, and where the machine cannot sufficiently clean the bedrock, this work is done by hand labour. The entire plant is supported on four bogie trucks which move on double tracks 12 ft. apart, laid on the bedrock. No jack-arms, side braces or spuds are used. Steam is supplied by one 50 h.-p. boiler to a set of dredging engines of the same capacity. These perform the excavations, handle the car, run the washer and trommel, and move the plant forward when required. The part of the machinery by which the excavating is accomplished is similar in design to that used for such purposes on steam shovels. The boom is 40 ft. long, and carries a dipper or shovel of $1\frac{1}{4}$ cubic yard capacity, and handles 70 cub. yds. per hour. The water supply to this plant for all purposes is 20 miner's inches.

In this gulch the bedrock lies some 16 ft. below the surface. Above this is the auriferous gravel on which is a considerable overburden of barren material. This latter is first stripped off and disposed of at the side without washing. The pay gravel is then taken up by the shovel and dumped into a car at the other side of the plant which runs on an incline. One end of this incline rests on a shoe set in solid ground on the bank of the cut, and the other terminates on the roof of the dredge. The car, when filled, is handed up by a cable, operated by the engines and pumped into a hopper on top of the plant. The gravel passes into a washer and trommel, when complete disintegration is effected, and the coarse gravel and rocks passed out at the rear end of the plant. The finer gravel, sand, gold, and water pass through the perforations of the trommel into a sluice box originating immediately below. This sluice extends some distance behind the plant, being carried by suspensory chains for regulating the grade. The saving of gold accomplished in this system is 97 per cent. and 98 per cent. The machine has operated ten hours every day since May 18th, with the exception of Sundays and one day while awaiting material with which to make repairs. Eight and sometimes nine men have been employed, three of whom do the work of cleaning the bedrock by hand. About $1\frac{1}{2}$ cords of fir wood are consumed per shift of ten hours.

This dredge is the first of this design to be constructed. Others are being built which will embody improvements that have been suggested by the work done here."

Before concluding, I desire to convey my thanks to the Honourable H. J. Cadman, Minister for Mines, Mr. H. J. H. Elliott, Under Secretary for Mines, and numerous engineers and other residents of Otago, for the great kindness shown to me, and for the assistance they rendered me in obtaining the information set out in this paper.

DESCRIPTION OF PLATES.

Plate I.

The Chicago Dredge.

A tailings elevator is here seen at work, and the variation between the height of the loosely stacked tailings and the face of ground being attacked is apparent.

Designed and built by Mr. K. S. Sparrow, engineer, Dunedin.

From photograph by W. Esquilant & Co., Dunedin.

Plate II.

The Moa Dredge.

It has been one of the most successful dredges upon the Clutha. The picture shows it working in the Clutha River a short distance below Alexandra.

Originally constructed according to the design of Mr. E. Roberts, and recently altered by Messrs. Cutter Brothers. From photograph by W. Esquilant & Co., Dunedin.

Plate III.

The Molyneux Hydraulic Co.'s Dredge.

This is probably the largest machine working at the present time upon the Clutha. The great length of the elevator (60 feet) enables the tailings to be stacked at any height not exceeding 35 feet. These are two revolving screens.

A nozzle has been erected upon the bow of the pontoon, so that when a steep bank is being attacked the ground can be "hydrauliced" in advance, and the risk of the ladder and buckets being buried beneath heavy falls thereby minimised. It is doubtful whether the advantages accruing from the use of the nozzle compensates for the large amount of power which it consumes.

At the time of my inspection the dredge was working into a face of gravel 25 feet high.

Designed by Mr. E. Roberts, consulting engineer, Dunedin. Reproduced from photograph by W. Esquilant & Co., Dunedin.

Plate IV.

The Earnscleugh No. 1 Dredge.

This dredge is represented leaving the Clutha River, and commencing to attack a river flat.

Designed by Mr. E. Roberts, consulting engineer, Dunedin. Reproduced from photograph by W. Esquilant & Co., Dunedin.

Plate V.

The Manorburn Dredge.

Here a dredge is seen exploiting an auriferous flat away from the river altogether. It is cutting a channel for itself, breaking down the bank of gravel in front, and stacking it, when delivered of its gold, behind.

The ladder, with the system of gear pulleys used for raising and lowering, are well shown.

Designed by Messrs. Cutten Bros., Consulting Engineers, Dunedin. Reproduced from photograph by W. Esquilant & Co., Dunedin.

Plate VI.

The Enterprise.

An historic interest is attached to this dredge, in so far as it was the first one to be supplied with an elevator for the tailings. The elevator is shown at work.

Designed by Messrs. Cutten Bros., Consulting Engineers, Dunedin. Reproduced from a photograph by W. Esquilant & Co., Dunedin.

Plate VII.

The Perseverance Dredge.

A "current wheeler" is here shown at work in the centre of the Clutha River, a short distance above Alexandria.

These machines being dependent upon the current for power can only work where the stream flows rapidly.

From photograph by W. Esquilant & Co., Dunedin.

Plate VIII.

A portion of the Manukerikia River, with alluvial flats which are about to be exploited by dredges.

From photograph by W. Esquilant & Co.

Plate IX.

A flat upon the Clutha, showing Hyde and party's No. 1 and No. 2 dredges and the "Perseverance" at work.

Plate X.

Electric Company's No. 2 Dredge.

The galvanised iron house not having been erected, the general arrangement of the machinery upon the pontoon can be seen.

The machine is remarkable on account of its long ladder. It can dredge to depths of 60 feet.

Two pairs of grab-hooks, which enable boulders up to a ton weight to be raised, will be seen upon the bucket belt.

From photograph given to me by Messrs. McGeorge, of Cromwell.

Plate XI.

Plan and sections of the A. E. Graeter dredge, which is working at Bannack, Montana, U.S.A. It differs from any of those upon the New Zealand rivers in being provided with two pivots, by means of which it can be anchored or moored short distances backwards or forwards.

The plate has been reproduced from that which accompanies the article on Gold-dredging in Montana, by Eugene B. Braden, "Engineering and Mining Journal," 20th November, 1897, p. 605.

Plate XII.

Plan and section of Matau Dredge, showin general arrangement of machinery.

This dredge has been designed by Messrs. Cutten Bros., Consulting Engineers, Dunedin. When completed it will be launched upon the Clutha River to work ground about 3 miles above Alexandria.

Reproduced from a photograph by W. Esquilant & Co., and supplied to me by Mr. W. H. Cutten.

Plate XIII.

The Kawarau dredge, designed by Mr. J. C. McGeorge, consulting engineer, Dunedin, to work very deep ground. It has the longest ladder of any machine in New Zealand. When launched, it was supplied with an elevator 25 feet long, and the revolving screen was lengthened 4 feet.

Drawings of an elevator, with chain of buckets detached, have been added. The plate has been prepared by Mr. O. Trickett, draughtsman to the survey, from the tracing which was supplied to me by Mr. A. McGeorge, engineer, Cromwell.

Reference to Plan and Section.

A. Gantry, with gear-pulleys for raising and lowering ladder.
B. Ladder.
C. Winches.
D. Anchor winch.
E. Engine.
F. Boiler:
G. Tumbler, driving bucket belt.
H. Revolving screen.
J. Screen pipe.
K. Screenings shoot.
L. Gold-saving tables.
M. Pump.
N. Starboard mooring lines.
O. Port mooring lines.
P. Head mooring line.

[Plates, &c.]

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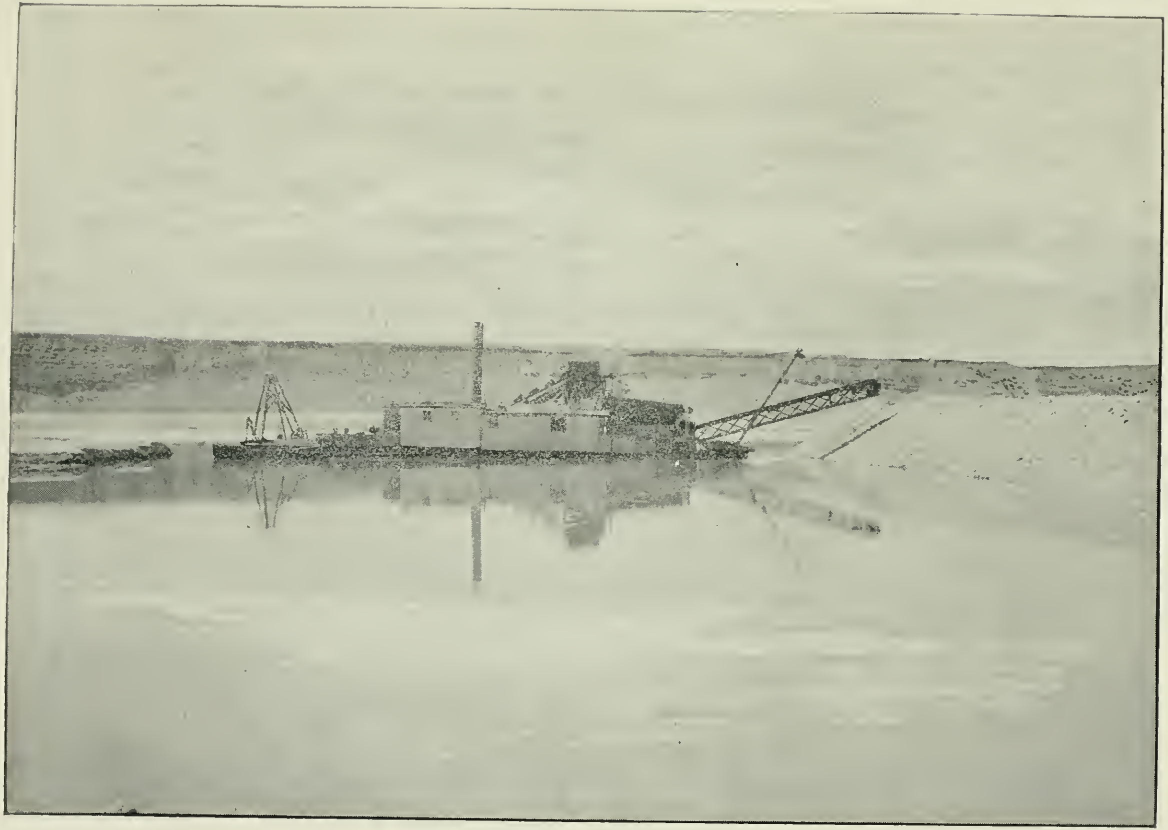
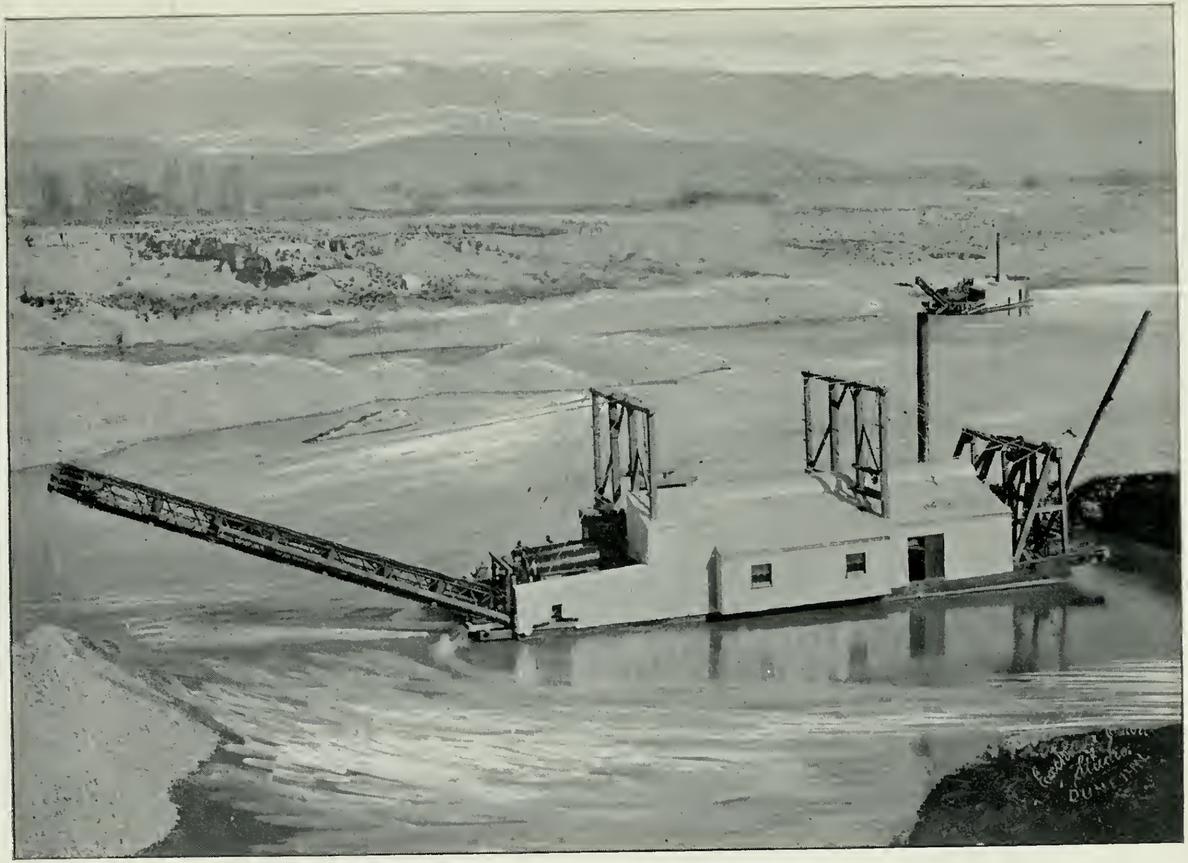


THE CHICAGO DREDGE.

THE MOA DREDGE.

PLATE III.

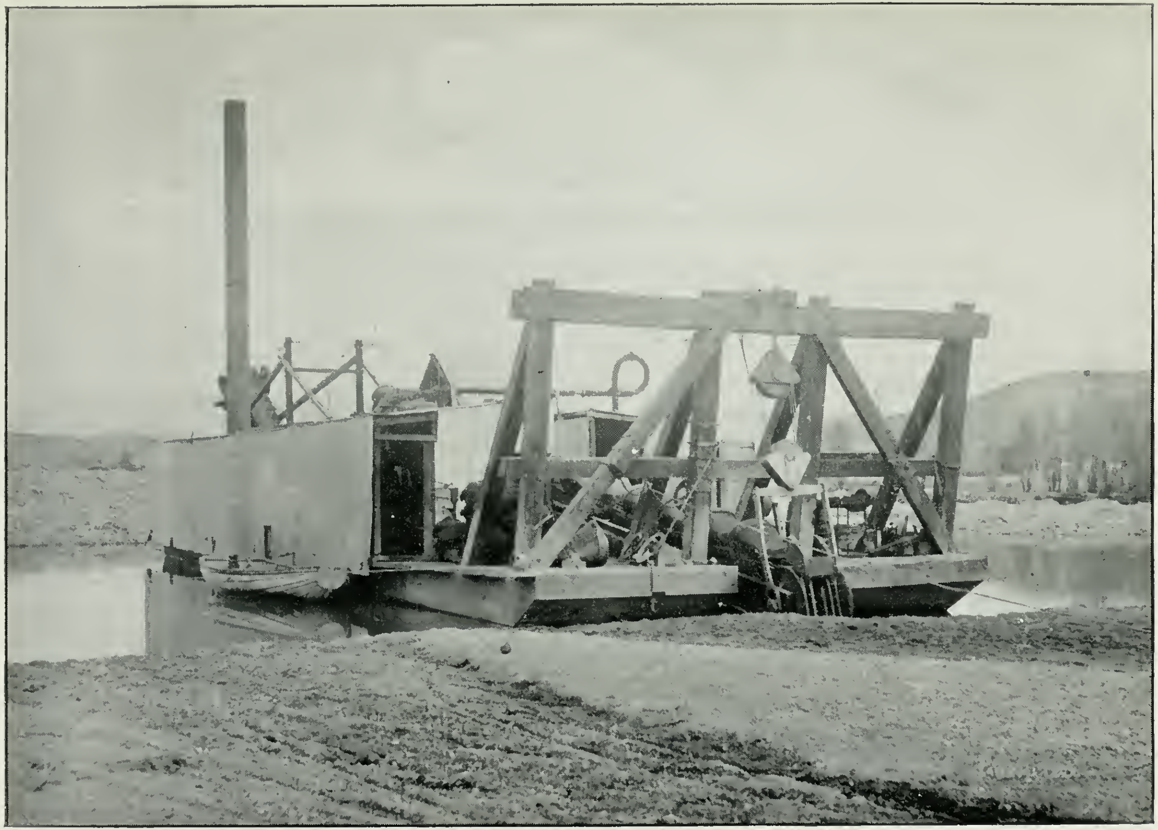


THE MOLYNEUX HYDRAULIC CO.'S DREDGE.

PLATE IV.

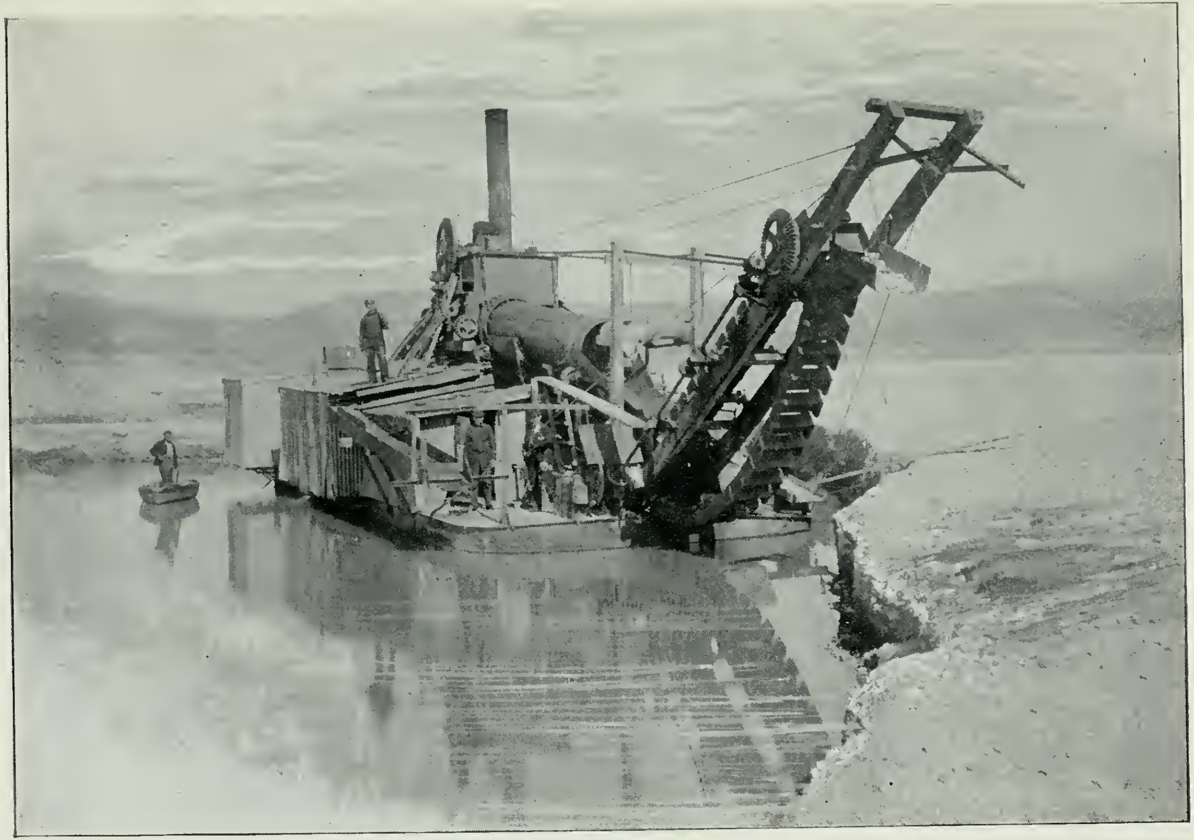
THE EARNSCLEUGH No. 1 DREDGE.

Plate V.



THE MANORBURN DREDGE.

PLATE VI.

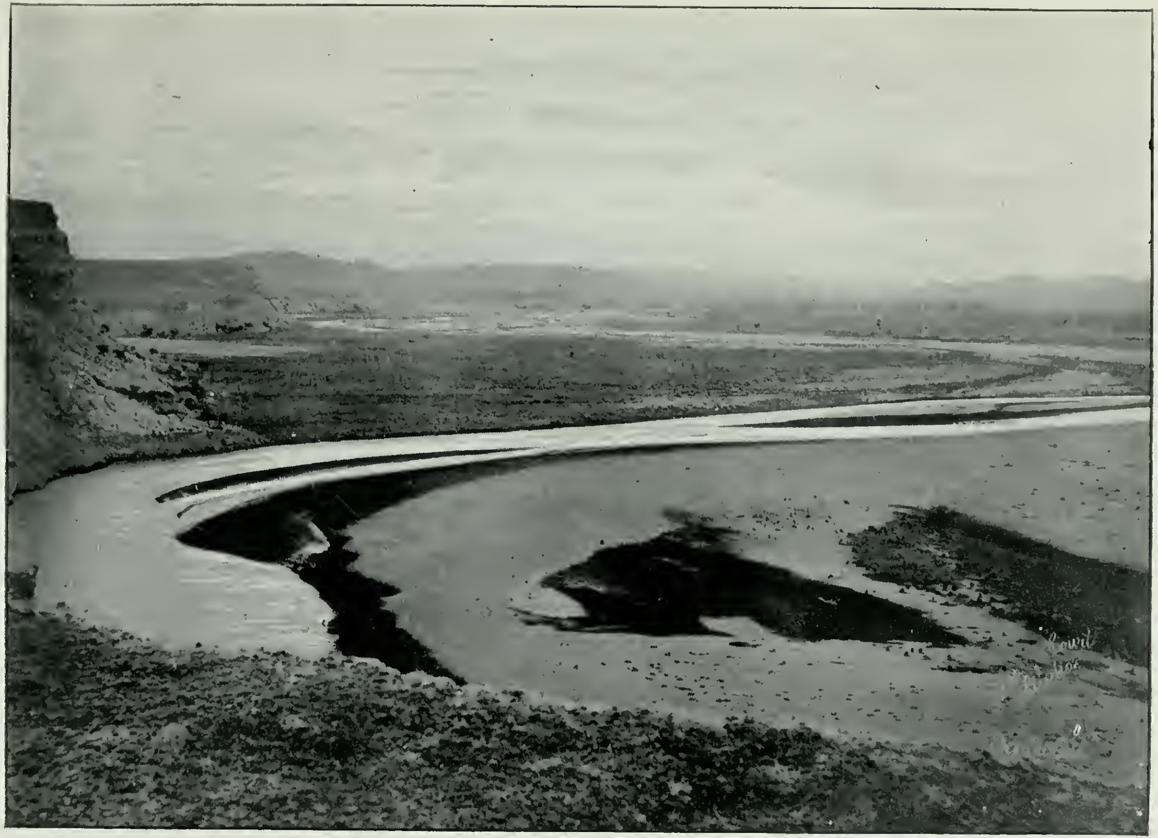


THE ENTERPRISE DREDGE.

PLATE VII.

THE PERSEVERANCE DREDGE.

PLATE VIII.

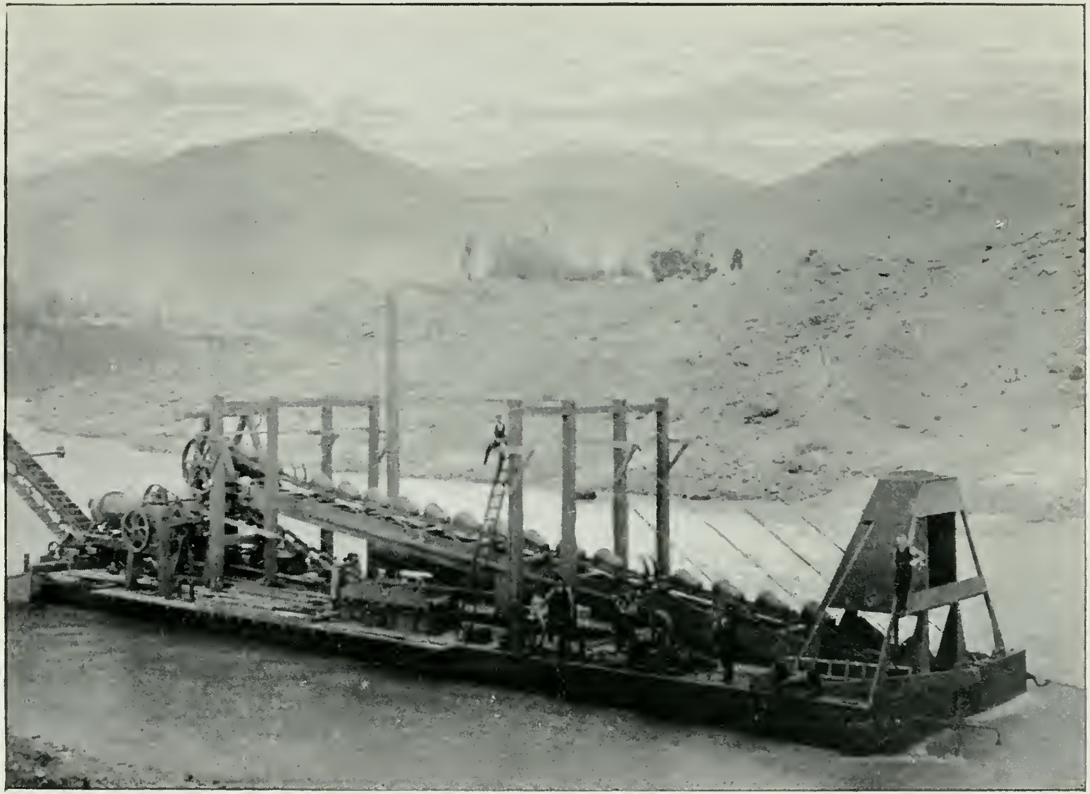


MANUKERIK!A RIVER.

Plate IX.

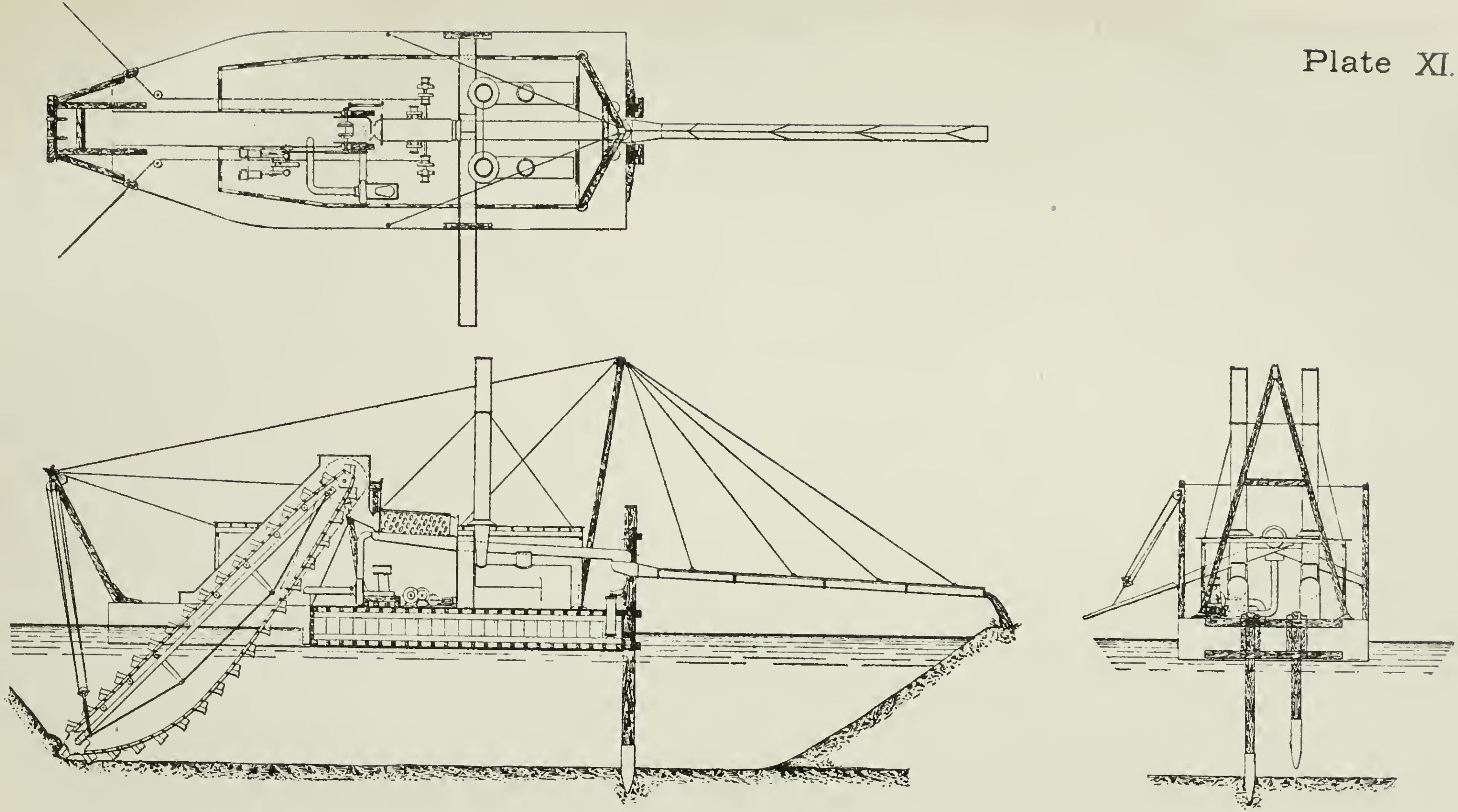
A FLAT UPON THE CLUTHA.

PLATE X.

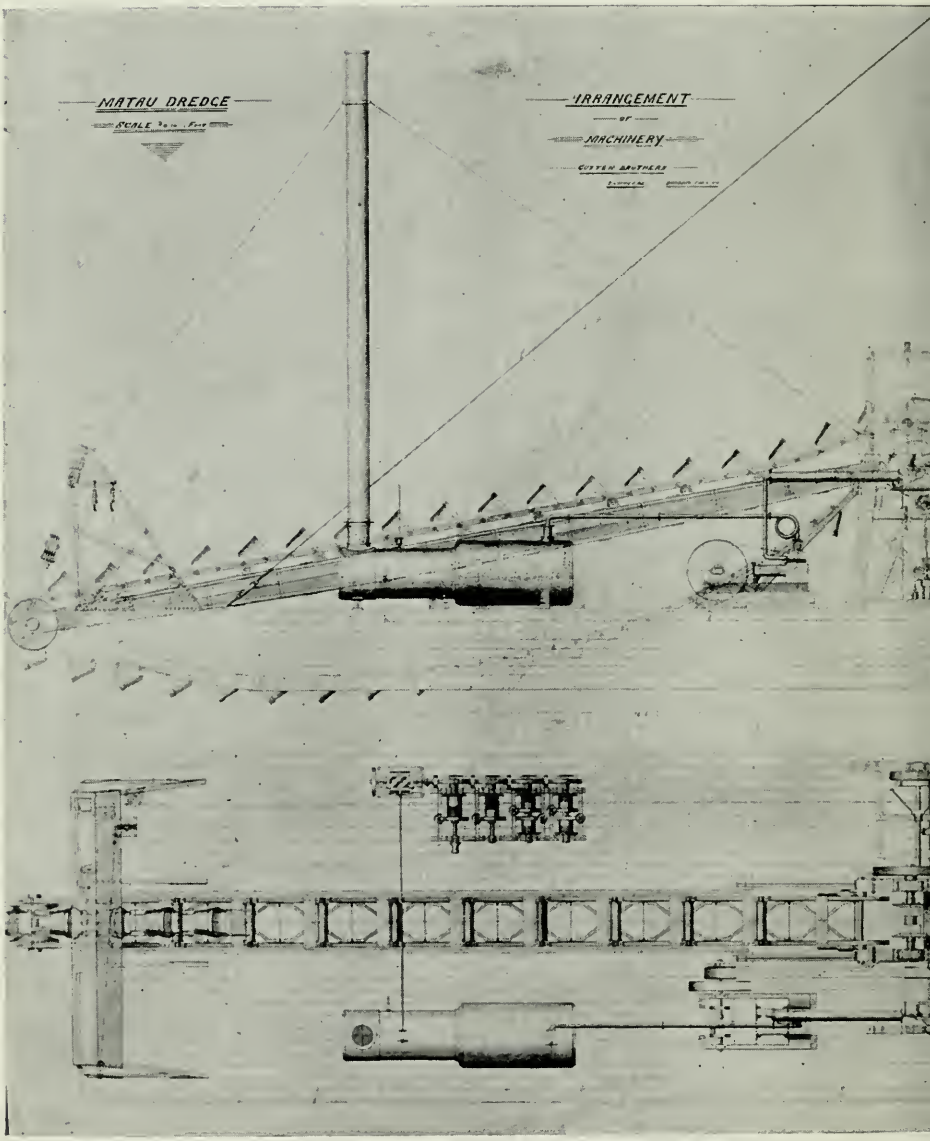


ELECTRIC CO.'S No 2 DREDGE.

Plate XI.

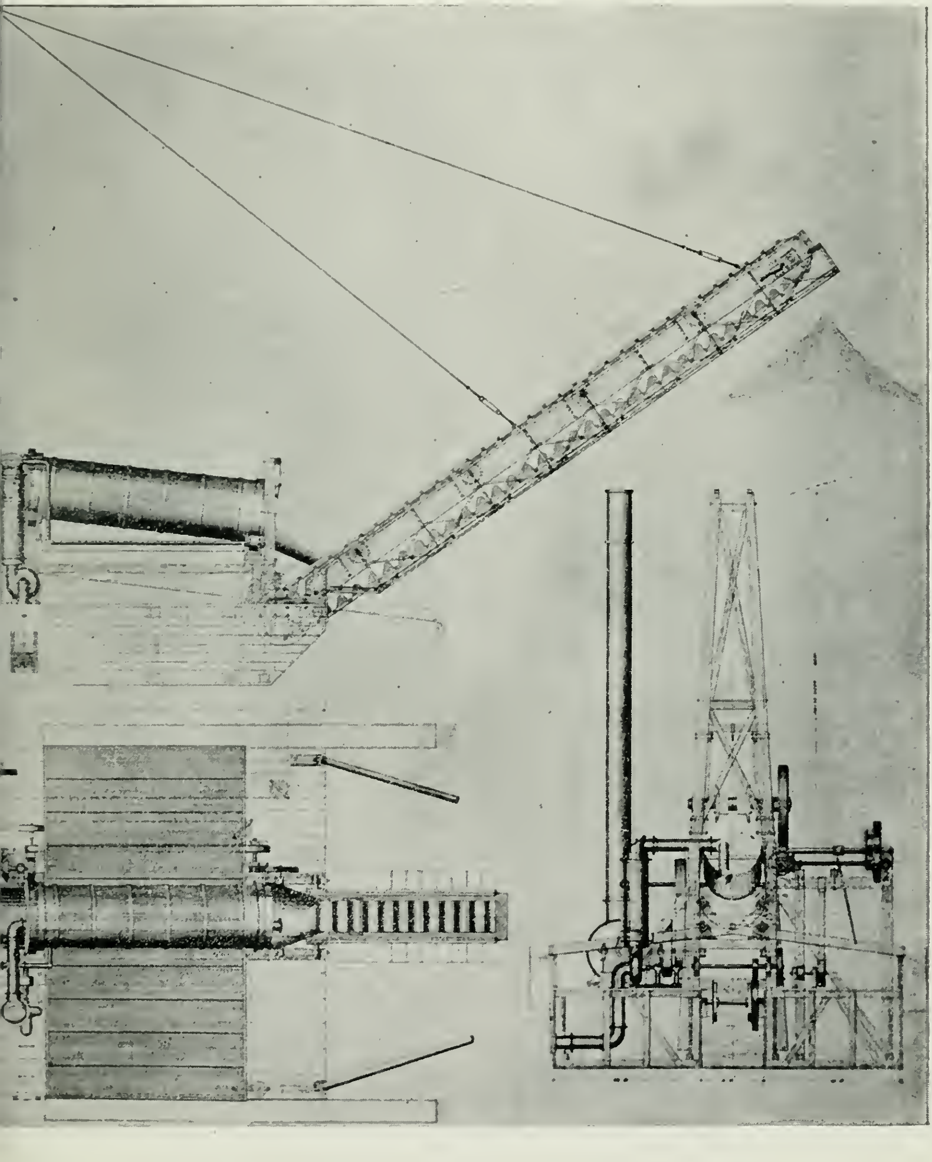


Plan and Sections of "A.E. Graeter" Dredge.

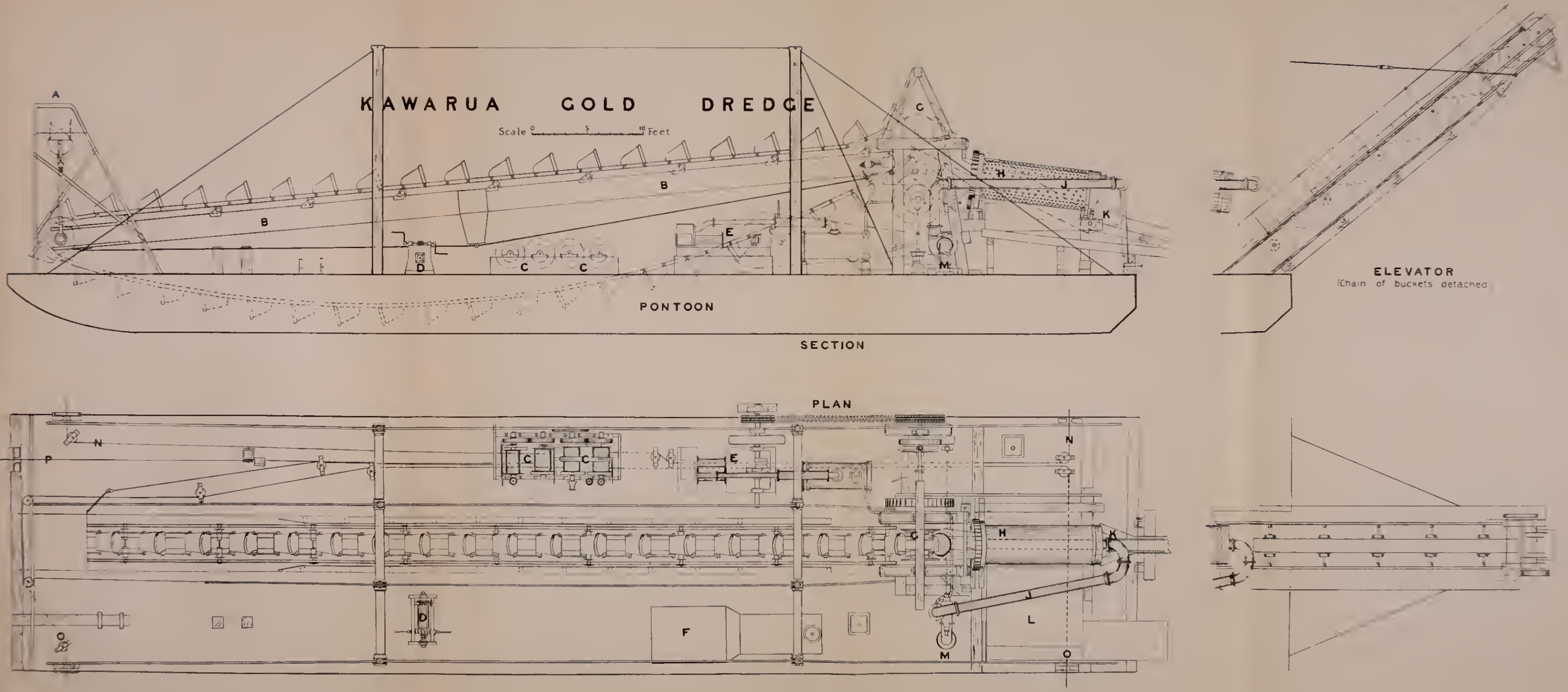


MATAU

XII.



REDGE.



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